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Strain and structural evolution in lead-free NBT-based piezoceramics

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High-performance $(Na_{0.5}Bi_{0.5})TiO_3$ (NBT) lead-free incipient ceramics are promising piezoactuator materials, but the high driving field limits their practical applications. Herein, we report a large piezostrain (d_{33}^*) of 810 pm/V at a low field of 4 kV/mm in the $(0.94\text{-}x)(Na_{0.5}Bi_{0.5})TiO_3\text{-}0.06Ba(Zr_{0.05}Ti_{0.95})O_3\text{-}x(Sr_{0.8}Bi_{0.1}\Upsilon_{0.1})TiO_{2.95}$ solid solution with x=0.05 (SBT5). The dopant induces a randomly distributed local polarization field, which boosts the ferroelectric instability and favors a more disordered relaxor structure. The driving field is notably reduced compared with other NBT-based ceramics, while its strain maintains at a high level along with a high thermal stability. The high strain in SBT5 is due to a field-induced reversible relaxor-ferroelectric phase transformation, while the reduced driving field results from two synergistic effects: remanent quasi-ferroelectric order as the seed for the growth of polar domains helps the system skip nucleation process; the local defects further facilitate the growth of ferroelectric domains. The composition, temperature and electric-field dependence of structural evolutions were systematically elucidated from micro- and macroscopic view. This study opens up a feasible and effective way for achieving a giant electrostrain in lead-free actuator materials.